Shelf-Slope Stability Assessment from Multiresolution (Wavelet) Estimation of Slope and Curvature from Gridded Bathymetry Data

Jeffrey K. Weissel
Colin P. Stark
Lamont-Doherty Earth Observatory of Columbia University
Palisades, New York 10964
phone:(914) 365-8533, (914) 365-8742; fax: (914) 365-8156;
email: jeffw@ldeo.columbia.edu , cstark@ldeo.columbia.edu
Award#: N00014-96-1-0027

LONG-TERM GOAL

The overall goal of this study is to assess slope stability in the STRATAFORM study areas of The U.S. continental margin. The general procedure for slope stability assessment employs a Coulomb failure criterion which assumes accurate knowledge of local topographic or bathymetric slope.

OBJECTIVES

The research objective is to develop new techniques for making "best" estimates of local bathymetric slope gradient from bathymetry containing errors and artifacts for use in slope stability studies. This work is important because gridded bathymetry data, which we need to use in slope stability studies on continental margins, contain swath-parallel, edge-like artifacts owing to seawater refraction correction errors. These artifacts prevent determination of bathymetric slope gradient with the resolution and accuracy required for reliable slope stability assessment.

APPROACH

Non-linear, wavelet-based signal decomposition methods are a promising way to reduce swath-edge artifacts often found in gridded bathymetry data. These methods have several advantages: We can a) make good use of the localization, scale, directional selectivity, and phase sensitivity properties of wavelets (Fig. 1), and b) choose wavelet shapes that "mimic" the artifacts we wish to remove (Fig. 2).

The methodology follows closely the "Matching Pursuit" algorithm *(Mallat and Zhang,* 1993; *Bergeaud and Mallat,* 1995) which iteratively decomposes a signal *f* by selecting from a redundant dictionary of elemental waveforms • • chosen to best represent the coherent structures of the signal. The dictionary elements • are indexed by their position, dilation (scale), polarization angle (directionality), and their phase. Different dictionaries can be built for different wavelet "families". The algorithm quickly and efficiently removes the coherent structure in signals leaving a residue with a random noise nature. Because the signal decomposition conserves energy, the unwanted swath-parallel artifact components (whose orientations and scales are known a priori) can be penalized during signal reconstruction.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **Shelf-Slope Stability Assessment from Multiresolution (Wavelet) Estimation of Slope and Curvature from Gridded Bathymetry Data**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Lamont-Doherty Earth Observatory of Columbia University,Palisades,NY,10964-8000**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **See also ADM002252.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED

We have completed implementation and testing of a I -dimensional version of the algorithm using code obtained from the Courant Institute at New York University (http://cs.nyu.edu/faculty/mallat), and a Mathlab Toolbox package from the Department of Mathematical Statistics at the University of California, Berkeley (http://www-stat.stanford.edu/ wavelab). Preliminary results were presented at the Fall 1997 meeting of the AGU *(Weissel and Stark*, 1997). Work now is focused on the development and application of two-dimensional algorithms which must be used to ameliorate swath-edge artifacts in gridded bathymetry.

IMPACT/APPLICATIONS

The problem of swath-parallel artifacts in gridded bathymetry will be general one in shallow water areas of the continental shelves and slopes exhibiting large temporal variability in the water column. The methodology developed for artifact reduction in the STRATAFORM test areas is expected to be generally applicable elsewhere.

TRANSITIONS

The work on artifact amelioration in gridded bathymetry is an application (in part) of earlier work supported by ONR at the Courant Institute, New York University under grant # NOOO14-91-J-1967, in effect adding value to that previous ONR investment.

RELATED PROJECTS

A major outcome of the slope stability studies along the U.S. continental margin in the past year was the discovery of a system of en echelon cracks, resembling small offset normal faults, in gridded bathymetry and GLORIA sidescan imagery off Virginia and North Carolina *(Goff and Driscoll*, 1997). Our hypothesis is that these en echelon cracks represent the initial stage of slope failure of the outer shelf and upper slope, and are destined to become headwalls of future submarine landslides. A proposal to study these features using deeply-towed chirp sonar and side scan sonar was submitted to the NSF in August by Driscoll (WHOI), Weissel (LDEO) and Goff (UT Austin). A paper describing the system of cracks and their implications for future submarine landslides and tsunami hazards will be presented at the 1998 Fall meeting of the AGU.

REFERENCES

Bergeaud, F., and S. Mallat, Matching pursuit of images, *in: Wavelet Applications II*, H.H. Szu (ed.), *Proc. SPIE, 2491*, 2-13, 1995.

Goff, J.A. and N.W. Driscoll, Statistical analysis of continental slope bathymetry on the U.S. Atlantic margin: The evolution of canyon systems, *EOS Trans. AGU (Suppl.)*, 78(46), F350, 1997.

Mallat, S., and Z. Zhang, Matching pursuit with time - frequency dictionaries, *IEEE Trans. on Signal Processing*, 41(12), 3397-3415, 1993.

Weissel, J.K. and C.P. Stark, Slope estimation from noisy bathymetry using two-dimensional Hardy space wavelets, *EOS, Trans. AGU (Suppl.)*, 78(46), F33,1997.

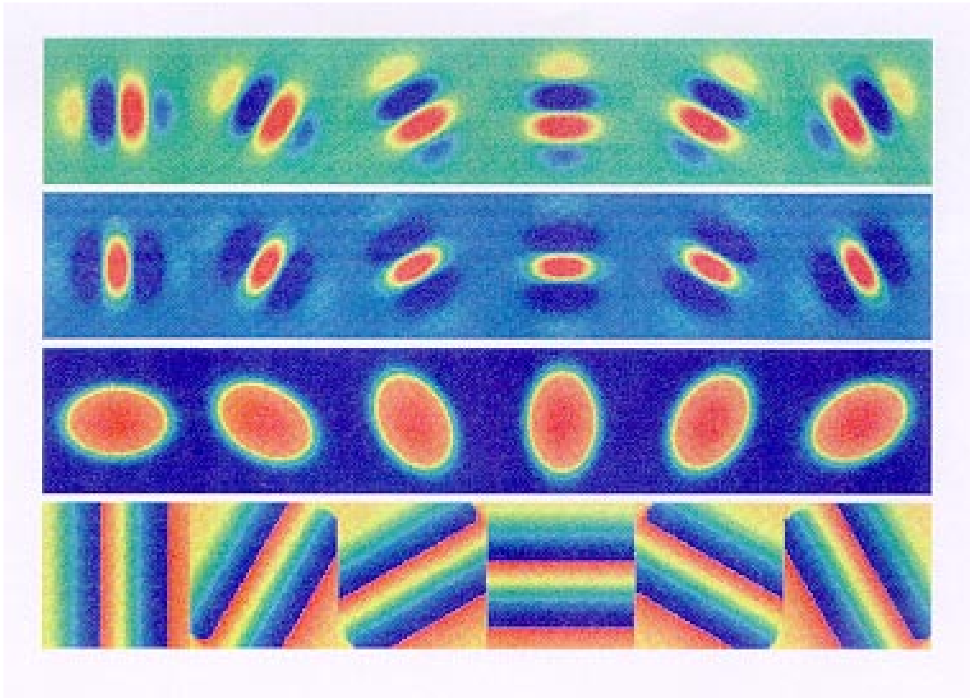

Figure 1. 2-dimensional, polarized, 3rd-order derivative Gaussian, Hardy space wavelets. From the top: real part, imaginary part (Hilbert transform), envelope (modulus), and phase (argument of the analytic signal).

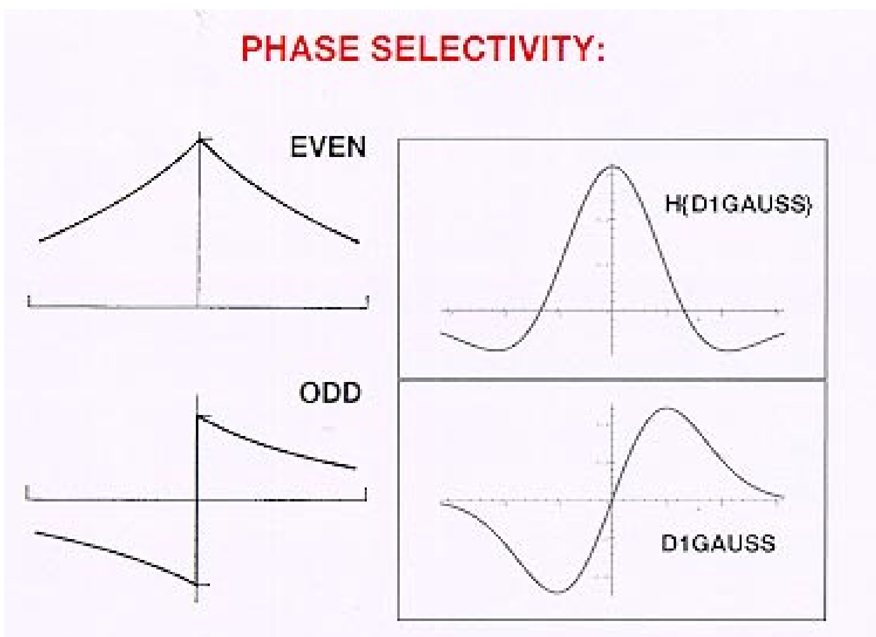

Figure 2. Wavelets (right) that "mimic" edges (left). The wavelets are the first derivative of a Gaussian (bottom right) and its Hilbert transform (upper right).